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# An Analysis of Peer Assessment Online Discussions within a Course that uses Project-based Learning

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In recent years project-based learning (PBL) incorporating online discussions has gradually been applied to courses that focus on writing projects. Past studies have shown that learners in PBL often face the difficulties of not having in-depth data analysis and peer discussions and how teachers design the rules and methods for online discussions has a significant influence on the quality of discussion. Since using a peer assessment strategy in the classroom could facilitate learners' critical thinking and meta-cognitive skills, this study conducts an empirical observational study in order to analyse the content and process of the discussion activities based on peer assessment without teacher intervention and tries to explore students' knowledge construction of the discussion. Sequential analysis and content analysis were conducted to observe the scale of each aspect of knowledge construction and the sequential pattern of students' knowledge construction during the discussions. Teachers didn't provide any guidance or intervention during the activity. Based on the results of the observations, this study discusses the possible difficulties that students may encounter when conducting peer assessment online discussions. Finally, this study also proposes suggestions about the timing and methods for teacher interventions.

## Introduction

Developing students' capabilities to cooperate, communicate, and make decisions is a critical task. Courses that focus on training students to complete their project reports independently also often emphasize developing the abilities to plan, discuss, and write reports as well. Project-based learning (PBL) is a learner-centred teaching strategy. It requires learners to gather information relevant to a topic, communicate and discuss this topic with other people, finish the reports, and then share what they have learned (Marx, Blumenfeld, Krajcik, & Soloway, 1997; Blumenfeld, Soloway, Marx, & Krajcik, 1994; Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Thomas, Mergendoller & Michaelson, 1999). Incorporating the above

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characteristics, PBL is one teaching method that is commonly used in higher education course settings. With advanced Internet technology PBL has also recently been commonly integrated into educational technology. Due to this, how to efficiently utilize the e-learning environment or computer-mediated communication tools in PBL has become a popular discussion topic.

After conducting a review of many studies on PBL Thomas (2000) pointed out that during the PBL learning process learners often face difficulties in aspects such as data analysis, making inferences, peer collaboration and discussions, and time management (Edelson, Gordon, & Pea, 1999; Krajcik, Blumenfeld, Marx, Bass, Fredricks, & Soloway, 1998). For peer collaboration and discussions conducted on the Internet, asynchronous forums are most commonly used. Many studies have shown that the design of rules and methods for online discussions is one of the most important factors influencing the quality of discussions (Hewitt, 2003; Patricia & Dabbagh, 2005; Swan, Shea, Fredericksen, Pickett, & Pelz, 2000; Vonderwell, 2003; Vrasidas & McIsaac, 1999). Therefore, how teachers make use of forums, design online PBL discussion activities, and provide students with guidance in a timely fashion will be the key components to determine whether PBL learners are able to conduct in-depth analysis and make inferences for a given topic. By observing and analysing the processes of particular online discussions, the results can also provide references for teachers to determine the timing and method of intervention in the discussions, as well as how to design their online discussion activities.

In addition, the implementation of peer assessment in the classroom has gradually received more and more attention (Cizek, 1997; Shepard, 2000). Previous studies have shown that peer assessment allows students to observe others' work, ask questions, and conduct discussions, which can improve students' critical thinking and meta-cognitive skills to a certain extent (Lin, Liu, & Yuan, 2001; Topping, 1998). To further examine how "peer assessment online discussion" can influence students' knowledge construction, this research thus integrates an online discussion activity that utilizes peer assessment into an actual instructional context in order to observe the process of knowledge construction from the content of students' discussions. To achieve this goal, this study adopted the interaction analysis model (IAM), a coding scheme designed by Gunawardena, Lowe, and Anderson (1997) that has been commonly used in analysing discussion content, to help us understand the scale of each aspect of students' knowledge construction. Process lag sequential analysis (Bakeman & Gottman, 1997) was used to analyse the process pattern of students' knowledge construction without teacher intervention. The results of the sequential analysis provide insights into how the students' discussion behavioural patterns are characterized. Furthermore, these results can also provide references for the design of better discussion activities in the future. To summarize, the objectives of this study were to:

1. utilize a "peer assessment online discussion" activity in a higher education PBL course and record the content of discussions;
2. use content analysis to investigate the scale of each aspect of knowledge construction in peer assessment discussion activities;

3. use sequential analysis to investigate students' sequential behavioural patterns in peer assessment online discussions;
4. investigate the difficulties faced by students during the discussions;
5. provide suggestions regarding teachers' interventions based on the results of the analyses.

## Discussion Mechanism and the Coding Scheme

Since the purpose of this study was to understand the discussion process of peer assessment, we first needed to decide how the discussion activities would be implemented and which coding scheme would be used in the in-depth analysis. Different discussion behaviours will be defined in order to code the posted messages and allow further content and sequence analysis. The mechanism of online discussion and the coding scheme are described below.

### *Peer Assessment Online Discussion Mechanism*

The peer assessment online discussion mechanism in this study was an instructional activity specifically designed for online PBL. The design of the entire activity was carried out according to the following steps.

*Step 1. Project report writing.* First, the teacher asked each student to complete a project report. The students needed to choose their own project topic and go on the Internet to gather, organize, and analyse information. The report was completed according to a unified format provided by the teacher, with the report being completed independently before a deadline given by the teacher.

*Step 2. Upload the report.* After the due date for report submission all students were required to upload the report file onto an online learning system provided by the teacher, so that the files could be downloaded and shared with their peers. This online learning system must provide relevant functions for online PBL; in addition to uploading of reports and downloading of reports by their peers, an asynchronous forum should be provided for peer assessment. The forum allowed the students to post new discussion topics and read each discussion topic, as well as posting replies to such topics.

*Step 3. Post an introduction topic.* After the project reports had been completed, each student was required to post a new discussion topic on the online forum to introduce their work. In this way, all students opened a topic for their own report. In the consequent peer assessment phase other students could enter the topic and comment on the report by posting relevant messages.

*Step 4. Perform peer assessment.* Finally, the teacher allowed students to download and view their peers' project reports after all students had posted the introductory topic on their report. The teacher asked the students to go into the forum, browse the list of

topics, and read the introductions written by their peers. Within a certain time limit the students were encouraged to post questions or comments directed at their peers and reply to questions or comments directed at them.

### *The Coding Scheme for the Content Analysis*

In order to understand knowledge construction in the discussion process, the IAM coding scheme proposed by Gunawardena, Lowe, and Anderson (1997) was chosen for this study. This coding scheme is divided into five phases (as shown in Table 1), and each phase represents a type of knowledge construction of discussion content. This coding scheme has also been commonly used in the analysis of online discussions (Jeong, 2003; Marra, Moore, & Klimczak, 2004), so it could enhance the validity of content analysis (Rourke & Anderson, 2004). Jeong (2003), for example, has also utilized the IAM coding system to understand the content of online discussions formulated by students without teacher intervention. Learning from the experience of Jeong (2003), this study sought to understand aspects and the sequential relationship of knowledge construction by using the IAM coding scheme to code each posted message.

## Methods

### *Participants*

The 45 participants in this study were senior college students majoring in information management. The course they attended was a three credit course entitled

Table 1. Gunawardena, Lowe, and Anderson's (1997) interaction analysis model

| Code | Phase | Operation |
|---|---|---|
| P1 | Sharing/comparing of information | Statement of observation or opinion; statement of agreement between participants |
| P2 | Discovery and exploration of dissonance or inconsistency among participants | Identifying areas of disagreement; asking and answering questions to clarify disagreement |
| P3 | Negotiation of meaning/co-construction of knowledge | Negotiating meaning of terms and negotiation of the relative weight to be used for various agreements |
| P4 | Testing and modification of proposed synthesis or co-construction | Testing the proposed new knowledge against existing cognitive schema, personal experience, or other sources |
| P5 | Agreement statement(s)/application of newly constructed meaning | Summarizing agreement and meta-cognitive statements that show new knowledge construction |
| P6 | Others | Discussions irrelevant to knowledge construction |

"Computer-assisted instruction." The course topics included fundamental theories of e-learning, case studies, and how companies could utilize e-learning in their training programmes.

### *The Research Tool*

In order to observe the process of student online discussions, an Internet teaching environment was provided in which teaching took place. This environment also included asynchronous forums, which served as a tool to record the students' discussion processes. In this study the researchers incorporated the WIDE platform (Web-based Instructional Design Environment) (Chang, Sung, & Hou, 2006). WIDE is an online platform providing an environment for online teaching activities. Moreover, it fits in with the execution requirements of the above mentioned online PBL teaching activities. Table 2 lists the WIDE functions that relate to the online PBL activity of this research.

### *Procedures*

This study conducted a PBL activity, which was implemented from the end of March to the middle of May 2004. Combined with the above mentioned peer assessment online discussion mechanism, the teacher in this activity requested each student to complete a project report within one month. For this project each student was

Table 2. Functions related to online PBL activity that are provided by the WIDE system

| Function | Description |
|---|---|
| Upload teaching materials | The function allowed teachers to upload the related resource they gathered on the Internet as well as their teaching plans and materials onto the platform |
| View teaching materials | The function allowed students to download and read the teaching materials provided by the teacher |
| Upload project reports | The function allowed students to upload their report files |
| View peers' reports | The function allowed students to download and read their peers' reports |
| Asynchronous forum | The functions allowed students to conduct online asynchronous discussions. Three sub-functions are available:<br>1. List of topics. All topics posted will be listed for users to browse. The users can click the topic link to enter the page of a specific topic, read content of the topic and all responses addressing that topic<br>2. Post new topic. After the user enters title and content, the topic will be added into list of topics and arranged according to time sequence<br>3. Reply to the topic. The user clicks on this function to post a responding message on the page of a certain topic. After completion of the response, the reply will be added to the topic page |

required to independently seek out a functioning company, analyse its operational bottlenecks, and design an e-learning training plan for the company employees. Each student needed to upload the completed training plan to the above mentioned WIDE system and post a forum topic which explained the background to their chosen company and illustrated the e-learning training programme for the company. From 9 to 20 May 2004 all students were required to conduct peer assessment discussion activities, i.e. each student was required to browse their peers' reports and comment on them. The students were informed that this peer assessment activity was part of their semester grade and that the teacher would not participate with comments, replies, or guidance throughout the entire discussion activity.

### *Data Analysis*

Forty-five students participated in this study. With one project per student and one topic per project, there were 45 topics in total. There was a message board for each topic (including the introductory article, comments by other students, and replies by the student who studied the topic), with a total of 329 messages at the end of the activity.

The above data was then coded by a rater from the research group based on the above mentioned IAM knowledge construction coding scheme. The coding method used each topic as a unit and then coded each message within a topic based on chronological order. During the coding process, if there were two or more paragraphs within a message with different codes, such message were assigned two or more codes based on the order of the content (e.g. If the first section of a message belonged to the category P1 and the second and third sections belonged to the category P3, then the coding for this message would be P1, P3). At the end of coding each topic had a set of coding data, with a total of 332 codes having been produced. To further examine the reliability of the codes we randomly selected 167 messages (about 50% of the total messages) to be analysed by a second rater. The $\kappa$ reliability of the codes was 0.727 ($p < .01$). The coded data then underwent sequence analysis and content analysis for knowledge construction.

## Findings and Discussion

### *Analysis of the Scale of Each Aspect of Knowledge Construction in Student Discussions*

Among the 332 message codes, 70 P6 codes (e.g. discussions irrelevant to knowledge construction) were removed, leaving 262 codes. The total numbers and percentages of each code are shown in Figure 1.

The distribution of coding shows that in the process of student discussions knowledge construction was mostly P1 (sharing/comparing information or proposing similar ideas) (88.6%), followed by P2 (discovery and exploration of dissonance or inconsistency among participants) (11.1%). P3 (negotiation of meaning/co-construction of knowledge) (0.4%), on the other hand, formed only a very small part of the

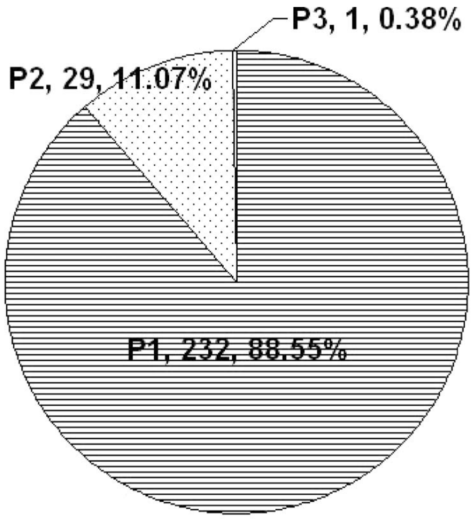


Figure 1. Scale map of the coding of knowledge construction in the online discussions

discussions. P4 and P5 were not observed. This finding suggests that some aspects of knowledge construction, such as P3, P4, and P5, are more difficult to achieve, which is similar to the results of research that used the same coding scheme proposed by Gunawardena, Lowe, and Anderson (Gunawardena, Lowe, & Anderson, 1997; Jeong, 2003). In order to observe the differences between ordinary online discussions and those involving peer assessment we also compared our findings with those conducted by Jeong (2003), which focused on free discussions on topics specified by a teacher who also did not intervene in the discussion process (P1 93.7%, P2 2.4%, P3 1.9%, P4 1.0%, P5 1.9%). The higher percentage for P2 (discovery and exploration of dissonance or inconsistency among participants) in our study shows that, since students were required to observe and comment on each other's work during the process of peer assessment, information is not only shared among students but different perspectives were also proposed, examined, and discussed, allowing this aspect of knowledge construction. The free discussions that did not involve peer assessment, however, were often limited to sharing and comparing information or proposing similar opinions.

This study has also discovered that, in the context of discussions with peer assessment, the addition of a peer assessment discussion mechanism did not increase the students' discussions of the aspects of P3 (negotiation of meaning/co-construction of knowledge), P4 (testing the proposed new knowledge against existing cognitive schema, personal experience, or other sources), or P5 (summarizing and showing new knowledge construction). This also shows that while the students could share their projects, propose similar ideas (P1), and explore and discuss their different perspectives (P2), they were unable to reach in-depth knowledge construction levels and negotiate knowledge meaning (P3), test the proposed new knowledge against existing sources (P4), or summarize and generate new knowledge (P5). This is similar

to the findings in the studies conducted by Jeong (2003) and Gunawardena et al. (1997). On the other hand, we also observed in our study that there were 70 P6 codes in the discussions (irrelevant to knowledge construction), which is 21.1% of the total 332 codes. This suggests that after a student's peers had made comments agreeing or not with the perspectives described in the student's report, the student's follow-up explanations or replies did not seem to address the knowledge content at a deeper level. Moreover, this 21.1% of the discussions was irrelevant to knowledge construction, straying from the main topics.

*Sequence Analysis of Students' Knowledge Construction Discussion Behaviours*

Using the above analysis of the scale of each aspect of knowledge construction we could only determine the percentage of each aspect of knowledge construction in the entire discussion. However, these percentages do not lead to a clear understanding of the students' behavioural patterns in the entire discussion process (in other words, the pattern of how the students finished a discussion based on a certain aspect of knowledge construction and then shifted to another discussion based on another aspect of knowledge construction). To address this issue we used sequence analysis, which would allow us to statistically examine which behaviours showed a significant sequence correlation and construct a diagram from this sequence correlation. Based on this information we could then infer the behavioural patterns that exist in the discussion process, which would facilitate our diagnosis of insufficiency in the discussions.

Thus, we compiled all the topics in the coding data, which included 45 topics with 329 messages. After coding there were a total of 332 codes. Since sequence analysis focuses on the tendency for a certain behaviour to immediately follow another, we calculated the frequency of each behavioural category immediately following another behavioural category (P4 and P5 were not considered as they did not occur). The results are listed in Table 3, in which each row represents the initial behaviour and each column is the code of the behaviour that follows immediately after the row behavior. The numbers in Table 3 represent the total number of times (total frequency) a column behaviour immediately followed a row behaviour in the total coded messages (e.g. 16 in row 2, column 1 means that P1 occurred immediately after P2 16 times). In order to infer whether each sequentce correlation reached statistical significance we conducted a sequence analysis (Bakeman & Gottman, 1997) based on the information listed in Table 3. The results were used to form the adjusted residuals table (Table 4), in which if the *Z*-value of a sequence was greater than $+1.96$, then the connectivity of this sequence reached statistical significance ($p < .05$). Based on Table 4 we were then able to draw a behavioural transition diagram (Figure 2).

Figure 2 demonstrates the sequences in Table 4 that reached statistical significance. The numerical values represent the *Z*-values for the sequences, while the arrowheads of different thickness represent different levels of significance and the transitional direction. From the information listed in Table 3 and Figure 2 we can

Table 3. Frequency transition table

| | P1 | P2 | P3 | P6 |
|---|---|---|---|---|
| P1 | 140 | 20 | 1 | 32 |
| P2 | 16 | 5 | 0 | 5 |
| P3 | 0 | 0 | 0 | 1 |
| P6 | 30 | 4 | 0 | 32 |

Table 4. Adjusted residuals table (*Z*-scores)

| | P1 | P2 | P3 | P6 |
|---|---|---|---|---|
| P1 | 3.98 | 0.30 | 1.22 | −6.82 |
| P2 | −0.24 | 1.60 | −0.33 | −0.59 |
| P3 | −0.81 | −0.32 | −0.06 | 1.53 |
| P6 | −2.56 | −1.35 | −0.62 | 5.13 |

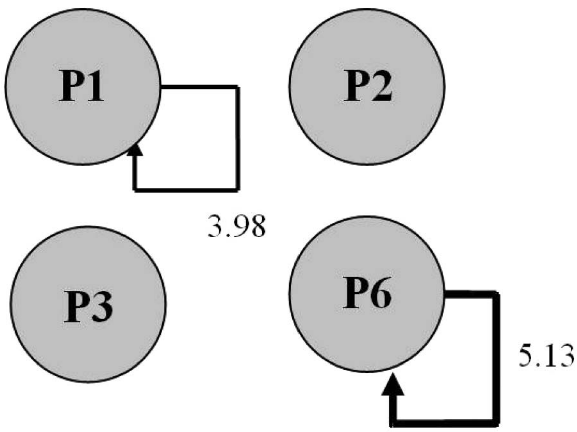


Figure 2. Behavioural transition diagram for peer assessment online discussions

obtain a basic understanding of the sequence tendencies of the students' behaviours. The patterns of behavioural transitions have been compiled and are listed below.

1. During the entire discussion process, the sequences that reached significance were only P1 → P1 and P6 → P6. The other sequences did not reach significance.
2. The behaviours P1 (sharing, comparing information or proposing similar ideas) and P6 (messages irrelevant to knowledge construction) show a tendency of repeated occurrence, and both have no sequence correlations with P2 or P3.

Looking at P1 → P1, we can see that when the students share, compare, or propose similar ideas they also demonstrate a certain level of dedication or consistency in their discussion behaviours. However, their discussion behaviours do not have a sequence

correlation with other discussions related to knowledge construction. In other words, while the students shared or compared information or proposed similar ideas (P1), they were unable to extend their discussions or to propose or explore other perspectives (P2), negotiate knowledge meaning (P3), test the proposed new knowledge against existing sources (P4), or summarize and generate new knowledge (P5). Although, from the previous analysis, we had already determined that during peer assessment discussions the percentage students' behaviour proposing or exploring different perspectives (P2) occurred to a certain extent (11.1%), Figure 2 shows us that the behaviour P2 did not show continuity (P2 → P2) and had not formed a significant sequence correlation with other behaviours. On the other hand, P6 → P6 shows that once posting irrelevant discussion messages had occurred this behaviour showed a certain level of continuity, to an extent that affected normal discussions. The analysis in the previous section also shows that irrelevant discussions took up 21% of the total discussions. This possibly diverted the focus in the students' discussions to directions unrelated to the main topic.

To a certain extent these findings allow us to understand the limits to students' peer assessment online discussions when the teachers does not intervene in the process. By comparing the findings with the analysis in the previous section we can understand that student discussions mostly consist of sharing or comparing information or proposing similar ideas, followed by proposing or discussing different opinions. However, while having similar or different opinions about a certain project, the discussions failed to generate further aspects of knowledge construction. On the other hand, the irrelevant discussions observed in this study tended to continue and thus shifted the entire focus.

Insufficient depth and width of these discussions is similar to what was found in other studies on the implementation of online PBL. Some studies, for example, found that learners often directly viewed online resources as the "answer" to the project, without in-depth cognitive processing or discussion (Chang & McDaniel, 1995; Wallace & Kupperman, 1997), or they may make inappropriate inferences regarding the topic (Krajcik et al., 1998). Through the analysis conducted in this study we can see that even though utilizing the mechanism of peer assessment may provoke a certain level of behaviours related to knowledge construction when peers comment or offer different opinions (P2, 11.1%), the students seemed unable to extend the depth and width of their knowledge construction (e.g. generating significant sequences P1 → P2, P1 → P3, P1 → P4, P1 → P5, P2 → P3, P2 → P4, P2 → P5 in Figure 2), or conduct deeper interactive discussions, such as proposing new understandings by comparing what is being discussed with previous experience (P4 → P5) or exploring and proposing different opinions regarding the new understanding (P5 → P2).

In order to explore these findings and the possible causes of the phenomena further, we extracted the reply messages for the topic of student S041 in the discussion shown in Table 5, which allows ease of further discussion.

From the extracted discussion in Table 5 the following can be seen. First, S041's introduction to his report was too brief and there was no systematic abstract, which may affect the motivation for and depth of peer discussion. Second, student S005's

Table 5. Extraction of an actual discussion example (student no. S041)

| Message no. | Author | Content | Date & time |
|---|---|---|---|
| 4101 | S041 | My topic introduces a customer service teaching system for Company A | 24 April 07:50:21 |
| 4102 | S005 | I found that your analysis is exactly the same as S124 . . . so . . . did one of you two upload the wrong data? | 10 May 22:26:48 |
| 4103 | S041 | Well, if there is repetition, I will prosecute for breach of copyright! | 11 May 12:39:52 |
| 4104 | S007 | The font in your report is too small and I suggest a larger font, otherwise it's an difficult to read! | 11 May 14:42:15 |
| 4105 | S019 | Congratulations for you first, the content is very professional and the analysis is quite detailed. I could not pick out any faults, please keep up the hard working! Go go go! | 11 May 23:15:48 |
| 4106 | S012 | For this system, is it possible that students cannot effectively grasp the essence due to the rather extensive aspect of function, which causes poor learning efficiency? | 15 May 16:51:41 |
| 4107 | S041 | The system design adopts tables and procedures often used in companies; many settings and development tool items are omitted, so it will be faster in operation | 17 May 08:35:08 |

doubts about mistaken uploading of the file, the suggestion by S007 about font size, and the superficial praise from S019 did not address the knowledge aspect of the report. These may result in subsequent responses being irrelevant to knowledge construction (e.g. the reply by S041 to S005 in message no. 4103) and be the possible reason for a P6 → P6 sequence, which could also possibly affect the continuity of an entire knowledge construct.

As for the opinion of S012 and the reply by S041 (message nos 4106 and 4107), while S012 provided an opinion, he did not describe it in a precise and practical way (e.g. provide a description with actual examples or supplement with sufficient evidence to overcome the doubts). This may possibly cause a biased direction of inference or failure of detailed explanation in S041's reply (e.g. in this case, S041's reply did not completely answer the question raised by S012 and he did not describe what the so-called "many settings and development tools items" are or explain whether operation efficiency and learning efficiency directly relate to each other or not). From this it can be seen that if there is an incidence of insufficient information or imprecise explanation in the assessment discussion between students, deviation of explanation or inference in the reply can result, which interferes with the development of deeper discussions (e.g. P3, P4, and P5).

The above are blind spots identified by the analysis in this study. These blind spots tend to occur in online peer assessment discussions when teachers do not intervene in the process. This is exactly where teachers' timely and active guidance and/or

feedback are needed, as well as adding some rules for peer assessment that help deepen the discussions. Also, the findings of this study can be used to provide references for the design of discussion activities which promote those sequences that help to increase the depth of knowledge construction (e.g. P1 → P3, P1 → P4, P1 → P5, P2 → P3, P2 → P4, and P2 → P5). The three suggestions proposed by this study are listed below.

*1. Teachers actively provide guidance and feedback.* Teachers can observe students' comments and discussions regarding each other's works, determine the point in time when irrelevant discussions may arise or the discussions may halt (e.g. when insufficient information or imprecise inferences in various discussions irrelevant to knowledge construction in the above mentioned cases occurs), appropriately post messages, provide students with feedback, or provide students with useful information and statements to extend the discussions or to provide new thinking.

According to most of the relevant literature on PBL (Blumenfeld et al., 1991, 1994; Marx et al., 1997; Thomas et al., 1999) execution of a project includes data collection, data analysis, report writing, peer discussion, and results sharing. If the content of peer discussions provides in-depth and extensive consideration of the adequacy of three aspects of a peers' report, namely data collection, data analysis, and report writinging, such discussions may enhance the project quality of all students. When digression occurs or the depth of discussion is limited, the teacher can determine whether the students' discussions address these three aspects of the peer reports. If digression occurs, an initial reminder should be provided, e.g. "Your discussion appears to digress; please discuss data collection, data analysis, and report composition for the report produced by your classmate." In the case of limited depth of discussion we suggest that the teacher analyse the direction of the students' discussion (e.g. data collection, data analysis, or report writing) and the reasons for the limited discussion (e.g. mistaken inferences, insufficient information, or imprecise expression) to determine a guidance strategy. For example, when the teacher discovers a "mistaken inference" during a discussion on "data collection" in a certain student's report he/she could post a guidance message, such as "I would like to remind students who offer comments to reach inferences after reading all data collected in the classmate's report in detail, such that wrong discussion is prevented". In this way students are offered the opportunity to be introspective and reach deeper inferences, which are expected to produce a further level of knowledge construction (P3, P4, or P5).

*2. Formulate a standard in-depth discussion format.* Since this research has found insufficient or imprecise information in students' discussion content, which generates consequent mistaken inferences, we suggest that the teacher revises the original discussion rules and drafts fixed format student discussions, e.g. when students make comments to their peers they should be required to follow a standard format in which they need to provide (a) their comments, (b) supplementary information or evidence,

and (c) suggestions in a way that gives the recipients or other participants enough information to reply or add new supplementary information. On the one hand, this allows students who are making comments to go through a deeper analysis before doing so. On the other, providing evidence, comments, and suggestions helps provide more information that has been considered by others , which may stimulate more in-depth discussions and reasoning, taking the discussions to deeper levels.

*3. Integration of intelligent agent technology.* Intelligent agent technology is capable of providing automatic feedback and guidance (Aroyo & Kommers, 1999). From the system aspect, if this technology can be integrated into the original asynchronous forum timely extraction and analysis of information, such as relevant data mining calculations concerning the behaviour of those taking part in the discussions, the content of the discussions, or the history of the discussions, can be executed. This technology will provide teachers with timely references to design feedback and guidance strategies, or actively offer students auto-generated guidance or supplementary information during their discussions; supplementary information automatically extracted from a database of teaching material can be used for the student's reference.

## Conclusions

It is important to determine whether learners undertaking online PBL can take in online information and conduct meaningful analysis or exploration directed at the topic (Land & Greene, 2000). In this process discussions among peers allow a deeper analysis and exchange of information. In order to understand how online peer assessment discussions are applied in PBL, what the insufficiencies in student discussions are, and how teachers can intervene, this study employs content analysis and sequence analysis to observe the process of online discussions based on peer assessment. This empirical study has found that prior to teacher intervention the students demonstrated a certain level of discussion behaviours related to knowledge construction (in terms of sharing information and proposing ideas). However, this study also found that extended discussions (including exploration of knowledge and meaning, examining the difference between new and old knowledge, and proposing new understanding) is not easily generated by peer assessment alone. It requires active teacher feedback and guidance or formulation of more sophisticated rules for discussion activities that may deepen knowledge construction in online discussions of PBL. However, factors influencing the depth of discussion could possibly include learners' attitudes to peers' comments and the length of time for assessment. These issues, as well as the process after involvement of the teacher and an intelligent agent, could be key points for further research.

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